Calorimeter Electronics R&D

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sPHENIX C&S Review

Design Drivers- I

- Compact Electronics- limited space on detector
- Common Electronics Design
  - Reduce design cost and time
  - Use off the shelf components
  - No custom ASICs
- Optical Sensors
  - Immune to magnetic fields
  - Compact
  - High gain

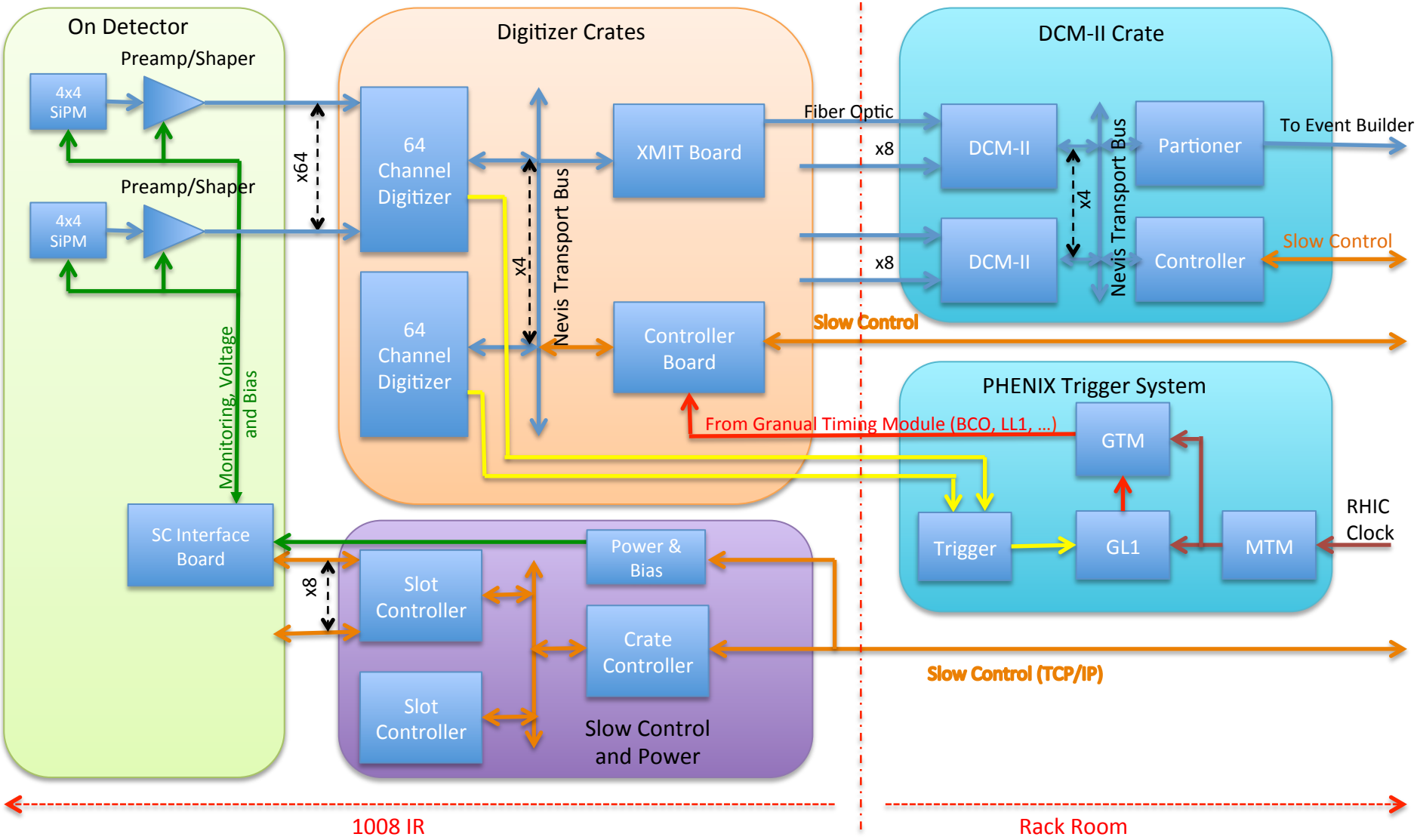
Design Drivers- II

- Direct digitization of signals
  - 40 BCO latency for trigger
  - Multi-event buffering
  - Reduced demands on analog section
- Compatible with PHENIX DAQ
  - High rate: 15kHz L1 trigger rate

Design Specifications

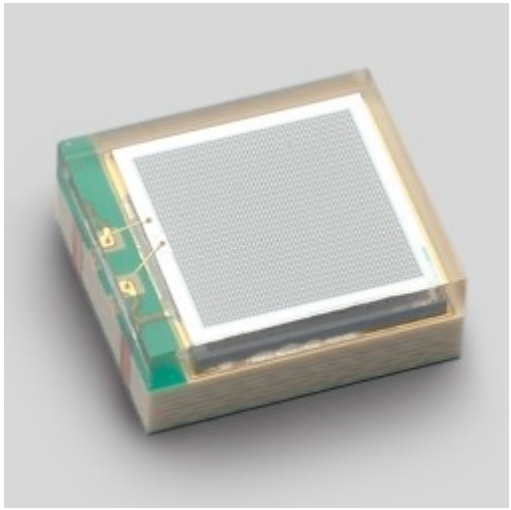
- Optical Sensors:
  - Dynamic Range: 10^4
  - Gain: 10^5
  - Photon Detection Efficiency: 25%
- Analog Front End:
  - Signal-to-Noise: 10:1
  - Peaking time: 30 nSec
  - Gain: 100 mV/pC
- Digitizer:
  - Resolution 14 bits (12 bit effective)
  - Maximum sampling frequency: 65 MHz
  - Latency (L1 Trigger): 40 Beam Crossings (BCO)
  - Multi-event buffering: 4 Events
  - L1 Trigger rate: 15 KHz

Calorimeter Electronics Overview



Calorimeter Electronics: Analog

- Solid state optical sensors
  - SiPMs are the preferred sensor
  - Reference design based on Hamamatsu S12572-015P
    - 3x3 mm^2
    - 15 μm pixel size, 40K pixels
    - Gain: $2x10^5$
    - EMCal: 98304, HCal: 15360
- Common front end analog electronics
  - On Detector
  - Low power
  - Shaper/Driver – 30nSec peaking time
  - More details by S. Boose

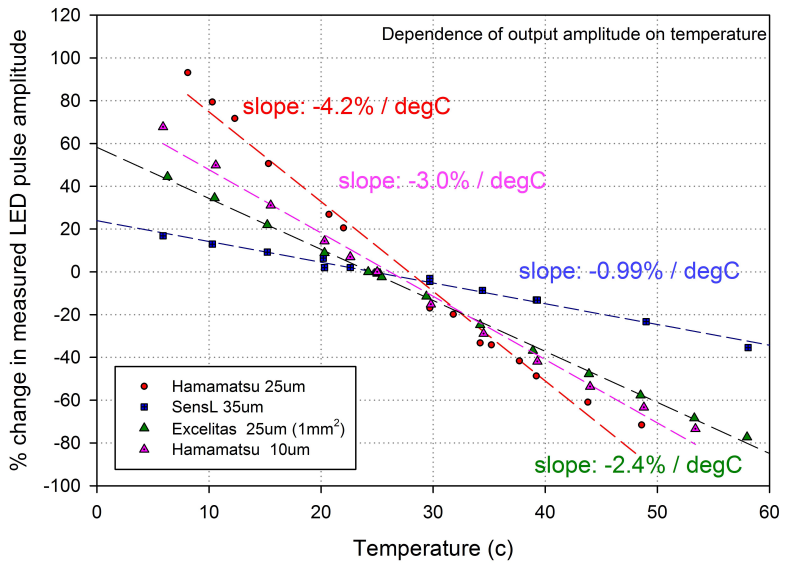


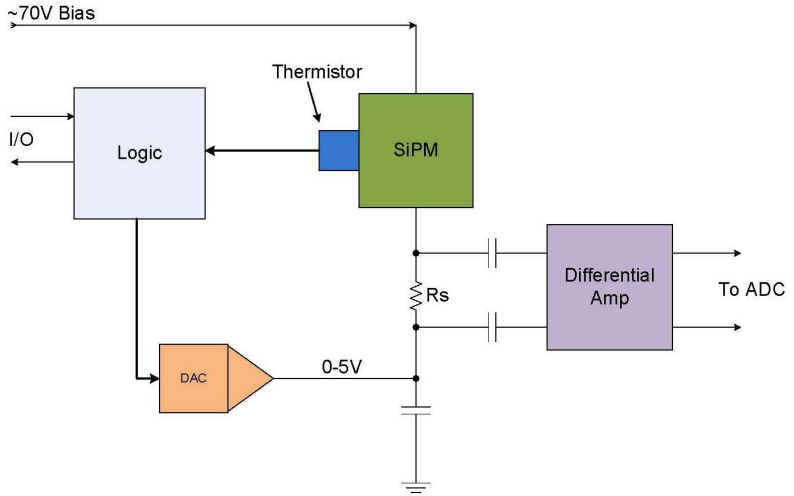
Calorimeter Electronics: Digital

- Located off (but near) detector
  - Reduced space constraints
  - Reduced cooling complexity
  - Easier access for installation and maintenance
  - Reduced magnetic constraints: e.g. allows use of DC-DC converters, inductors.
  - Need to pay attention to noise issues
- Continuous digitization of signals
  - 6x Beam crossing (BCO) frequency
  - 14 Bit ADC
  - Digital 40 BCO latency for L1 Trigger
  - Multi-event buffering
  - Provides trigger primitives
- More details by C.Y. Chi

Optical Sensors: Temperature Effects

- SiPMs have strong temperature dependence : 2%-4%/^{o}C
- Local monitoring of temperature
- Feed back loop to correct for temperature variations



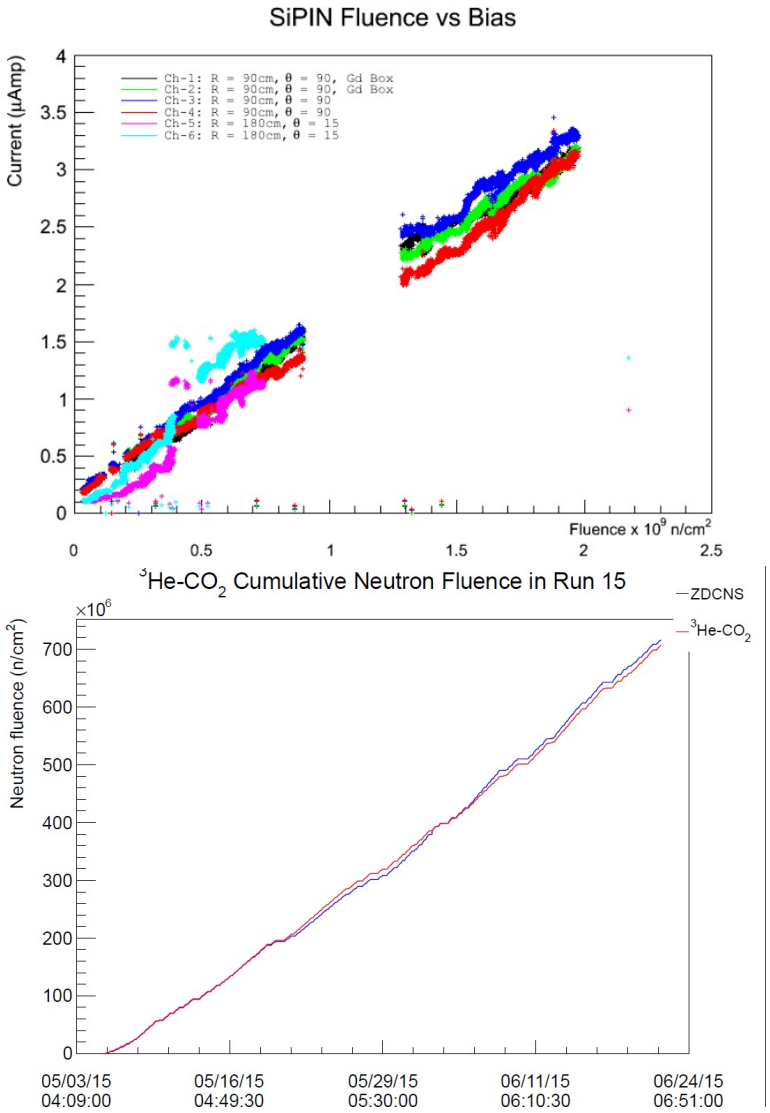


Radiation Tolerance Issues

- Expected Levels
  - Total Ionizing Radiation:
    - < 10kRad per Run
    - Highest rates are in 510 GeV/c p-p running
    - Based on measurements in 1008
  - Neutron Fluences
    - 2-3 10^{10} n/cm^2 per Run Year
    - Measurements in 1008
    - M.C. Simulations in STAR

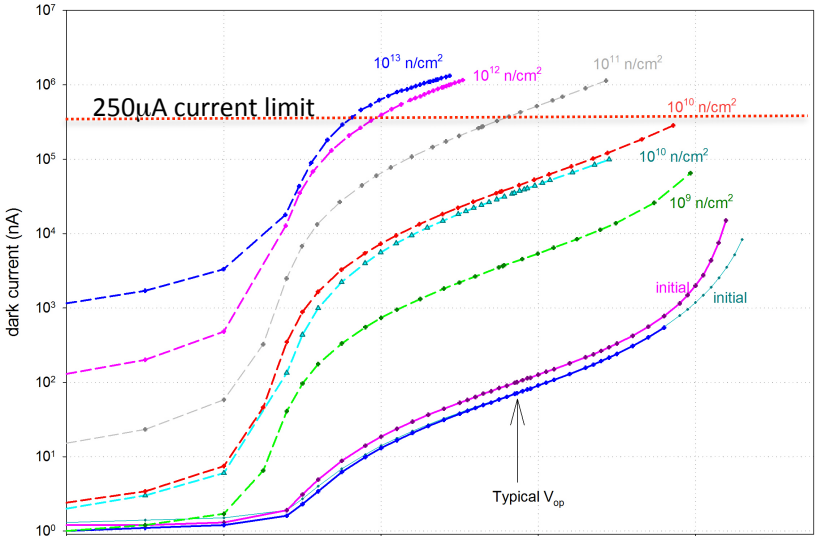
SiPM Neutron Radiation Damage

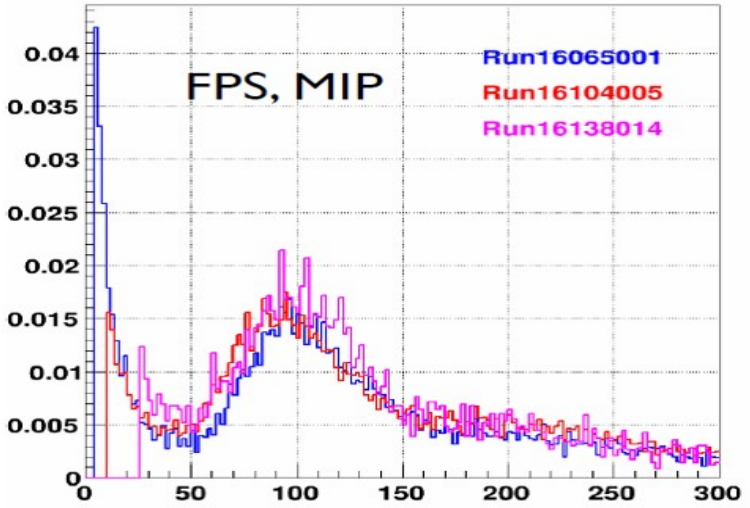
- SiPM susceptible to damage due to neutron radiation
- Results in increased leakage current
  - Increased noise
  - Decrease in PDE
  - Increased power
- Studies on neutron damage in progress



SiPM Radiation Studies

- PHENIX IR: Run 14/15
  - Neutron fluxes similar to what is expected for sPHENIX 2-3 x 10^{10} n/cm^2
  - Measure change in leakage current
  - Measure gain using LEDs
- LANCE (Los Alamos) and LENS (Indiana University) Studies
  - Much higher fluences- Equivalent to multi-years of running in a few days 10^{11} – 10^{13} n/cm^2
  - Study device characteristics pre/ post irradiation
- STAR is also doing studies

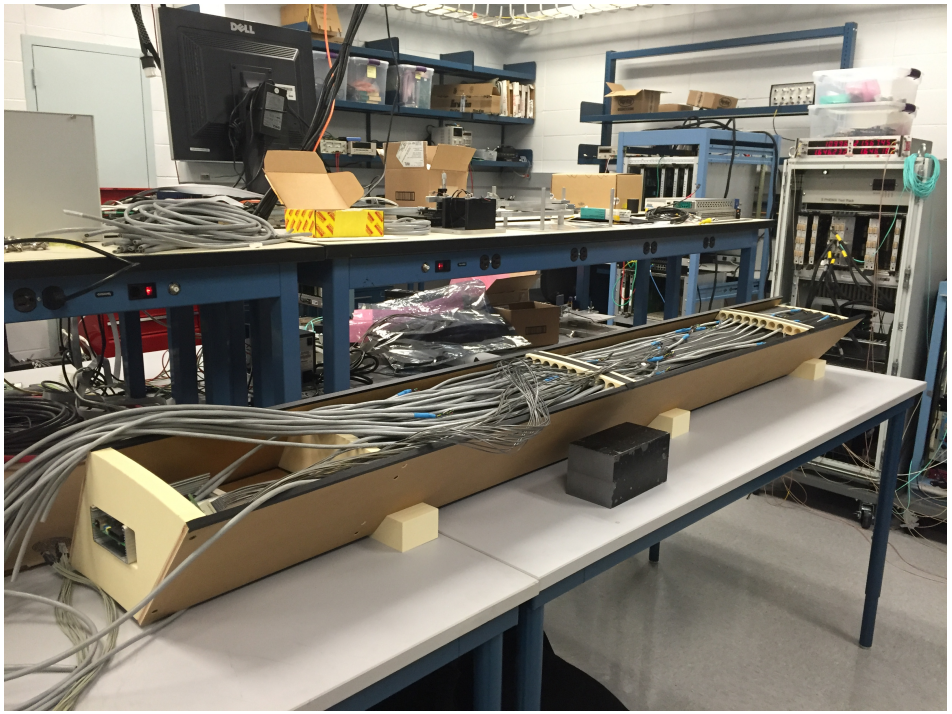




Cable Routing

- Integral part of electrical/mechanical design
  - EMCal has dense cable plant
  - Inner HCal is not accessible once installed
  - Has to address cooling

- Making dummy HCal/EMCal sectors to evaluate design
  - Inner ½ sector HCal complete
  - EMCal sector in progress
  - Outer HCal being planned



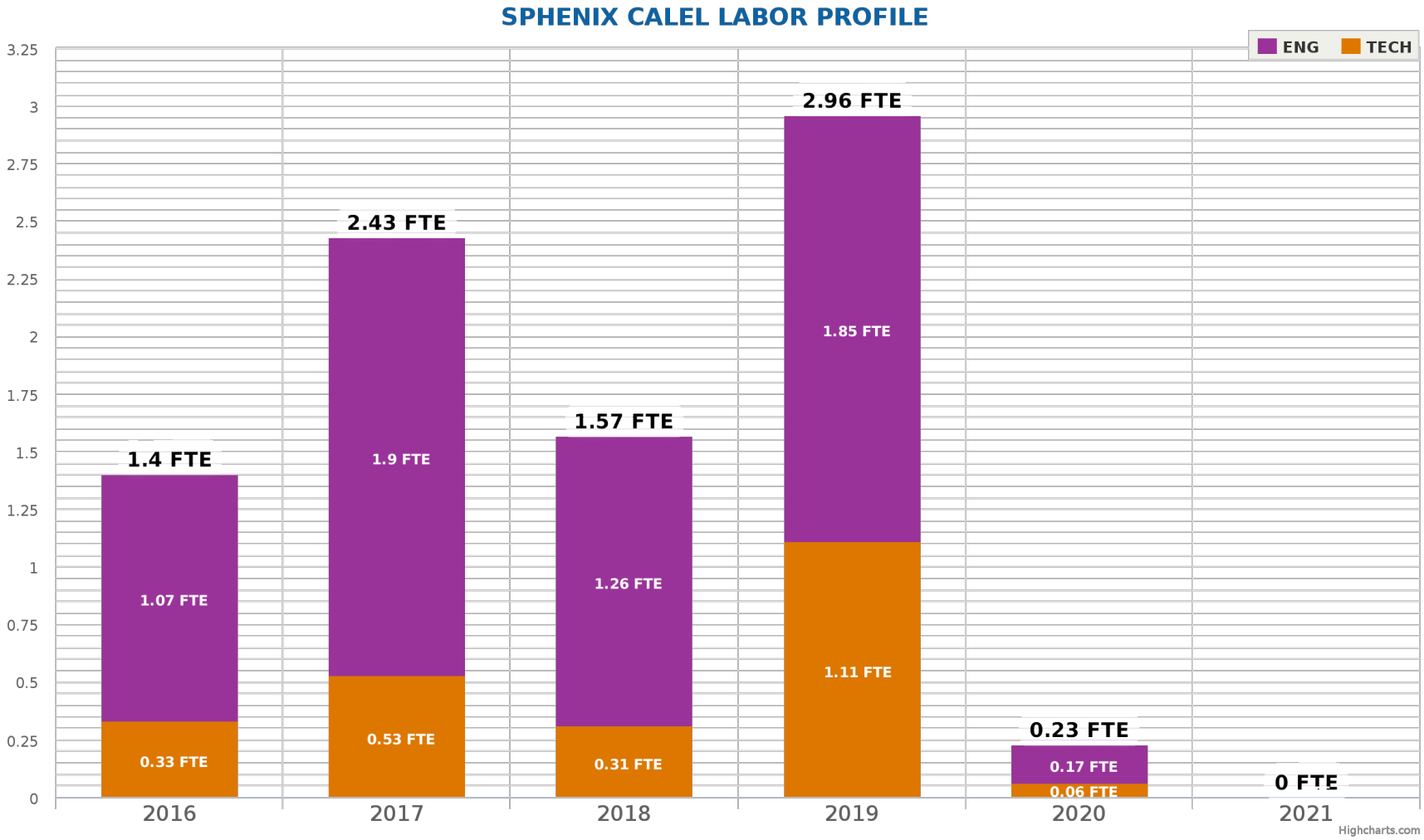
Prototypes

- Early test beam: T-1044 (March 2013)
  - Optical Sensors: 25 μm^2 SiPMs
  - First generation preamps
  - First generation controller
  - HBD Digitizers (48 channels/12 bit ADC)
- Prototype V1: T-1044 Follow up 1 (April 2016)
  - Optical Sensors: 15 μm^2 SiPMs
  - Second generation preamps
  - Second generation controllers
  - Second generation digitizers (64 channels/14 bit ADC)
- Prototype V2: Fall 2016/Winter 2017: Dates to be scheduled
- Preproduction Prototype

Future Radiation Studies

- Studies at 1008- PHENIX IR
  - SiPM performance
    - Measure gain stability
    - Leakage current
  - Analog component evaluation
    - Use first generation prototypes
    - Look for component failures
  - Making plans for RUN-16 (Jan 2016)
- Studies at LANSCE- Los Alamos
  - SiPMs
  - Front end analog section
  - Neutron fluences corresponding to multiple years of sPHENIX running
  - Next run opportunity Jan/Feb 2016

Labor Profile

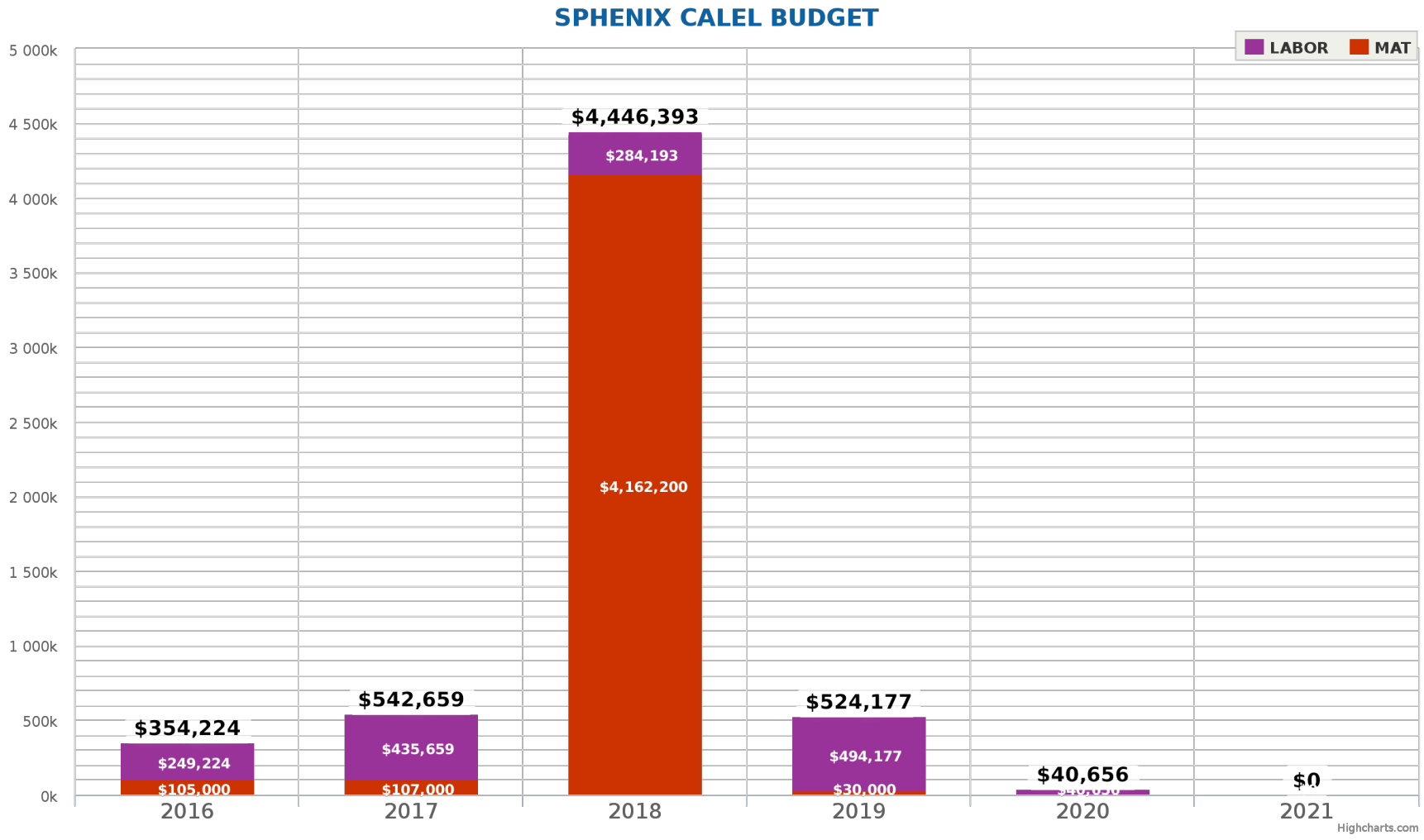


Cost Estimates

Based on:

- Number of modules required in reference design.
- Cost of R&D modules scaled to production quantities where possible
- Cost of similar or past produced modules if there is not yet an R&D version.
- Budgetary estimates for large cost items: SiPMs, FPGAs, ADCs, Signal Cables…
- Fabrication and assembly commercially done, only final assembly done in house.
- Continuing to refine as designs become more detailed.

Cost Profile



Issues and Concerns

- Neutron radiation damage: Continuing studies in progress
- Gain stability: Plan developed and being tested
- Radiation tolerance of devices: Will qualify all devices in "high" radiation areas.
- Signal Integrity (e.g.: cross talk, noise levels): On going studies in progress
- Ground Plan: Preliminary plan developed
- Cable Routing: Using mockups to finalize plan
- Prototyping: Multiple tests scheduled: Lab, Test Beam…
- Labor: Core group in place, BNL/Columbia, for design and fabrication, but will need to work with collaborators to finalize production testing stage.